Predicting the Impact of Seabed Uncertainty and Variability on Propagation Uncertainty

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Grant Number: N00014-07-1-0252

LONG TERM GOALS

Develop capability for quantifying, predicting and exploiting (QPE) the impact of seabed uncertainty on sonar system performance.

OBJECTIVES

The objectives are to: 1) develop techniques required to create a 2D geoacoustic uncertainty model (2D-GeUM) over an operationally significant area, 2) demonstrate techniques to create 2D-GeUM in area off northeast coast of Taiwan, and 3) demonstrate ability of 2D-GeUM to predict propagation uncertainty.

APPROACH

In order to predict the impact of seabed geoacoustic uncertainties and variability on propagation uncertainty along a radial of interest, a 2D geoacoustic uncertainty model (2D-GeUM) is required. Such a model quantifies depth- and range-dependent geoacoustic properties and their uncertainties over the area of interest. For the QPE experiment, the ~50 km x 50 km area of interest was off northeast Taiwan, including part of the Chilung shelf, the East China Sea shelf and upper slope.

The approach exploits direct-path wide-angle seabed reflection data and geologic modeling as the basis for generating the 2D-GeUM. The components of the approach are shown in cartoon form in Figure 1. The 2D-GeUM is the key model for predicting the impact of seabed uncertainties and variability on TL uncertainties along a specified radial. Preliminary results using data from a different shallow water area are promising in terms of capturing the correct propagation uncertainties.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2009**	2. REPORT TYPE **Annual**	3. DATES COVERED **00-00-2009 to 00-00-2009**

4. TITLE AND SUBTITLE **Predicting The Impact Of Seabed Uncertainty And Variability On Propagation Uncertainty**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **The Pennsylvania State University,Applied Research Laboratory,P.O. Box 30,State College,PA,16804**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Code 1 only

14. ABSTRACT
Develop capability for quantifying, predicting and exploiting (QPE) the impact of seabed uncertainty on sonar system performance.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

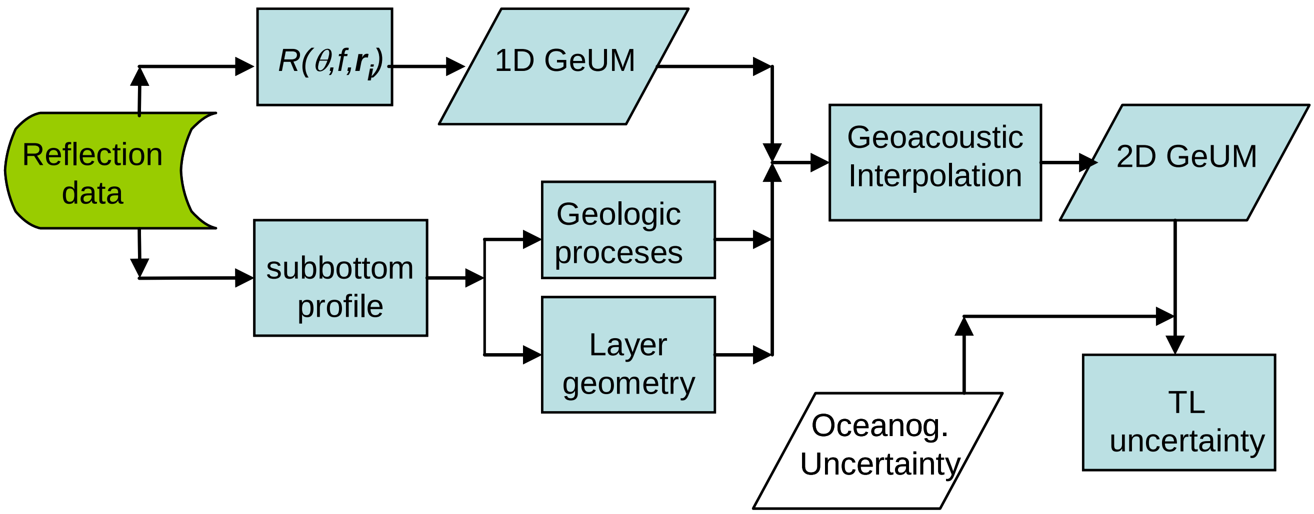

Figure 1. Approach to predicting the TL uncertainty with focus on quantifying the seabed contribution to uncertainty.

WORK COMPLETED

A short summary of FY09 efforts:

1. analyzed EK500 sonar data from the 2008 Pilot Experiment [1] to examine seabed variability

2. developed experiment plans for June 8-12, 2009 Geoacoustics cruise experiment, in collaboration with Jan Dettmer and Taiwanese partners ChiFang Chen and Linus Chiu

3. provided guidance on seabed uncertainty and variability issues for Main QPE Experiment. In particular provided maps, geoacoustic models, and suggested strategies for OMAS track lines.

4. developed experiment plans for September 3-7, 2009 Geoacoustics cruise experiment, in collaboration with Jan Dettmer and Taiwanese partners ChiFang and Linus Chiu

5. quantified perturbed physics geoacoustic uncertainties in seabed wide-angle reflection data (with Jan Dettmer and Stan Dosso, Un Victoria), [2]

RESULTS

Analysis of EK500 data from the 2008 Pilot Experiment

The 2008 Pilot experiment provided EK500 sonar data (courtesy of Glen Gawarkiewicz, WHOI) across the planned IOP experiment area. The data showed evidence of (what the author believes are) numerous fish schools, especially near canyon and other small-scale bathymetric features. It is possible that some are related to bubble plumes from methanogenic sources in the seabed (e.g., [3]), but this could not be confirmed.

The author attempted to use the EK-500 data (38 kHz) to probe spatial variability of the seabed in the planned experiment area using the magnitude of the seabed reflected return. This analysis was performed in the vein of a data-set of opportunity, i.e., using an instrument that was not designed for seabed studies. Difficulties with using the EK500 data included: 1) the system was not calibrated (thus reflection coefficients are relative not absolute); 2) the observed seabed reflected return included contributions from multiple mechanisms (which could not be untangled) including: the plane wave reflection coefficient, scattering from interface roughness, scattering from volume heterogeneities, and reflection from sub-bottom layers, 3) it is not clear how normal incidence 38 kHz seabed returns are related to low angle seabed interaction at the frequencies of interest to the QPE program (100 – 1000 Hz) and 4) there was very high ping-to-ping variability in the seabed reflections. Despite these difficulties, it was felt that some effort in analyzing the data was warranted, given the fact that there was so little data in the area that could be used to shed light on seabed property variability.

It was assumed that the observed ping-to-ping variability was due to the relatively narrow beam. That is, when the main lobe of the beam points off specular, the return is likely dominated by scattering, not reflection. In order to mitigate this variability, the median intensity reflection values were taken instead over 41 data samples each averaged over depth window of 1.25 m. This gave a reasonable compromise between lateral spatial resolution and stability of the results.

With the caveats above, there are trends in the data (see Fig 1) that might possibly be useful. Note that on most crossing lines, the reflection coefficient is reasonably consistent, giving some measure of confidence in the data. In terms of interpretation, if one suspects that the data are dominated by reflection and not scattering, the data suggest that the surficial sediments are harder to the northeast and softer to the southwest (except for a small soft area near Site A). Even at precisely normal incidence, though the signal includes a combination of reflection and scattering, and if scattering dominated the seabed returns, then another possible interpretation of the results is that the sediments are rougher to the southwest.

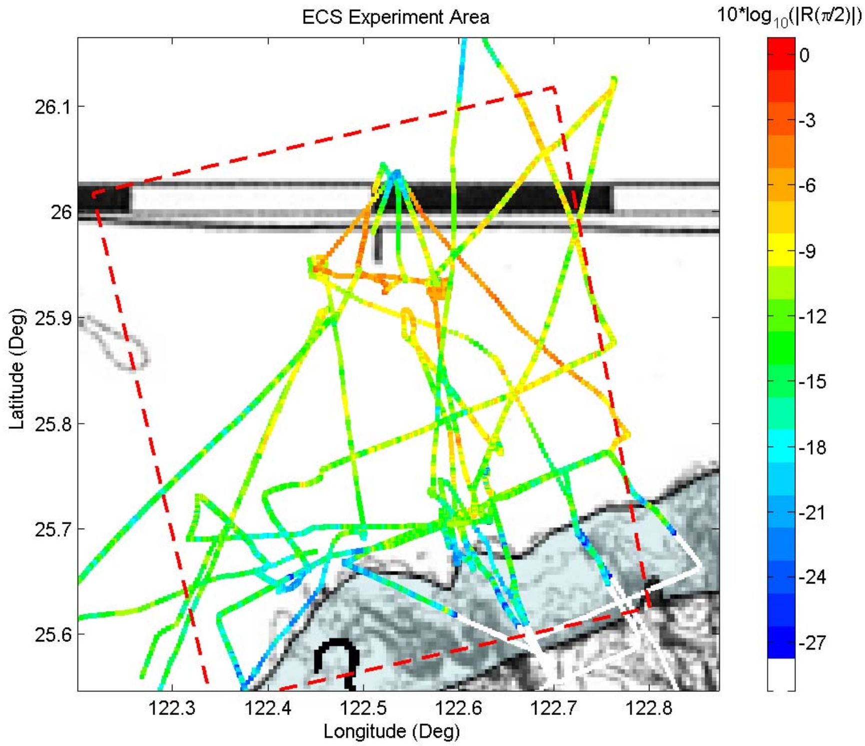

Figure 1. EK-500 data exploited to estimate seabed spatial variability in the experiment area. The quantity plotted is the relative seabed intensity reflection coefficient at 38 kHz at normal incidence (dB).

Experiment Planning and Conduct

The June 2009 Geoacoustics cruise plan employed a single phone SHRU receiver provided by Woods Hole Oceanographic Institute (WHOI), a rented Applied Acoustics Uniboom geophysical source, and an Edgetech SB-0512i chirp sonar provided by the National Taiwan University (NTU). ChiFang Chen and Linus Chiu (both of NTU) provided substantial assistance in coordination of the logistics and personnel for this cruise as well as coordinating use of the Taiwanese vessel Ocean Researcher-1 (OR-1). The objective of the experiment was to collect wide-angle broadband seabed reflection measurements at two main locations, termed Site A and Site B. At each Site, multiple wide-angle reflection measurements were planned with connective seismic reflection tracks. Planned tracks and SHRU locations are shown in Fig 2. Due to rough weather and equipment problems, useful data were not collected in the June campaign.

A second opportunity to conduct these measurements came during the main (IOP) experiment in early September, again using OR-1. In this experiment, the intent was to use both the single hydrophone SHRU as well as 4-5 four-channel SHRU's that were being deployed by WHOI in support of the OMAS propagation experiments (which employed a mobile acoustic source and fixed receiver). The sources for the wide-angle seabed reflection experiment included the Edgetech SB-0512i chirp sonar, a J-9 transducer, and a SQ-23 source, all provided by NTU. Again, substantial logistical help from the NTU collaborators was provided. However, due to rough weather during the period of the planned ops, no data were collected during this experiment.

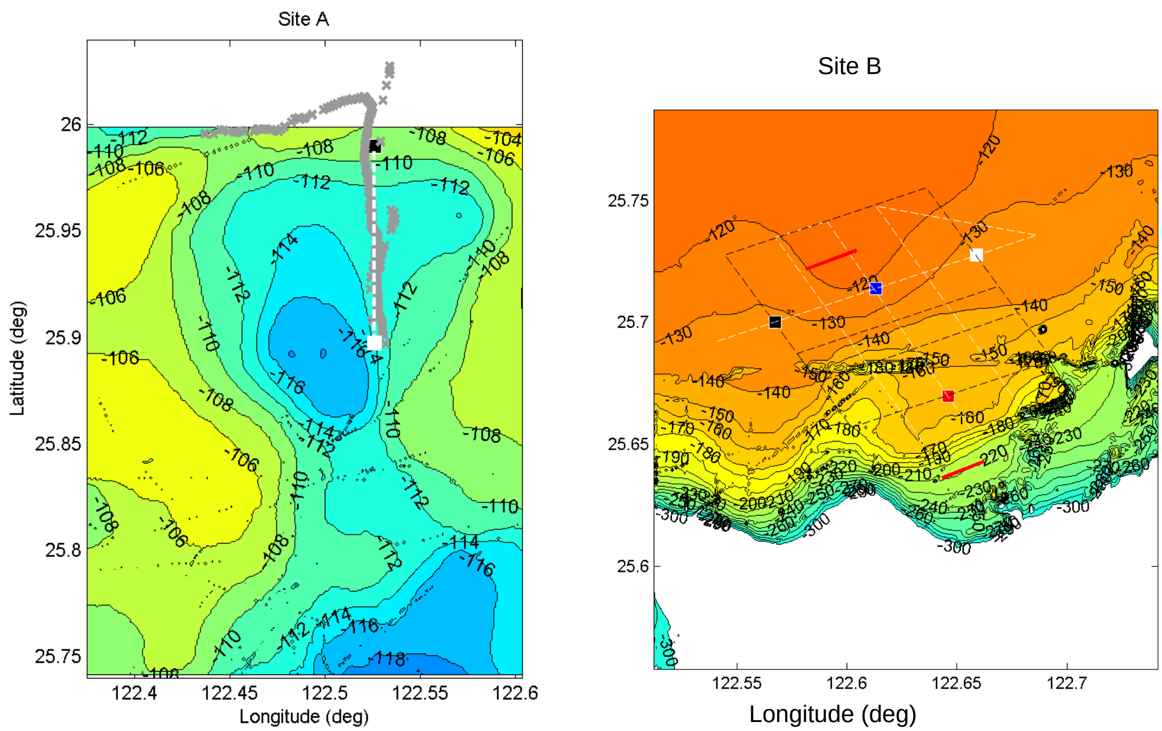

Figure 2. Planned seabed measurements for the QPE Geoacoustics cruise at Site A and Site B. Planned normal incidence seismic tracks are shown in dashed lines and wide-angle reflection measurements (SHRU locations) are shown in the boxes. Bathymetry contours are in meters.

Planned analysis

Although no data were collected in the planned areas to develop the 2D uncertainty model, other data sets exist (from the Malta Plateau in the Mediterranean Sea) that could be used to develop/demonstrate 2D geoacoustic uncertainty models. This possibility is under currently investigation.

IMPACT/APPLICATIONS

The seabed analysis results were employed to help in the siting of the main IOP experiment acoustic experiments. Also, progress in developing a perturbed physics approach to quantifying geoacoustic uncertainty has very broad implications for uncertainty estimation in the ocean acoustics community.

RELATED PROJECTS

ONR Broadband Clutter Joint Research Project: data collected in that project was used in QPE to test new advances in geoacoustic uncertainty quantification in preparation for the data collection effort. We are currently exploring using data from this project to develop a full 2D geoacoustic uncertainty model under the QPE program.

REFERENCES

[1] Gawarkiewicz, G., Sen, J. and Pilot PIs, “Quantifying, Predicting and Exploiting Uncertainty (QPE), 2008 Pilot Experiment; Aug 22- Sept 11, 2008 Technical Report”, Dec 2008.

[2] Dettmer J., C.W. Holland and S.E. Dosso, Resolving lateral seabed variability by Bayesian inference of seabed reflection inversions, J. Acoust. Soc. Am., 126, 56-69, 2009.

[3] Mud volcanoes at the shelf margin of the East China Sea, P. Yin, S. Berné, P. Vagner, B. Loubrieu, Z. Liu, Marine Geology, **194**, 135-149, 2003.

PUBLICATIONS

Dettmer J., C.W. Holland and S.E. Dosso, Resolving lateral seabed variability by Bayesian inference of seabed reflection inversions, J. Acoust. Soc. Am., 126, 56-69, 2009. [published, refereed]